PATENT ABSTRACTS OF JAPAN

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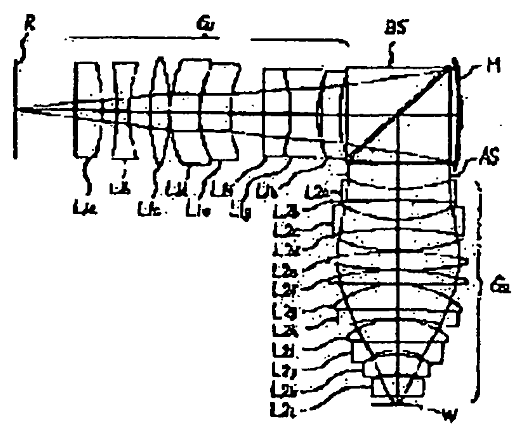
(54) REFLECTION REFRACTION OPTICAL SYSTEM

(57)Abstract:
PURPOSE: To obtain a large numerical aperture on the image side, to secure a sufficient working distance on the image side and to miniaturize a beam splitter by locating the rear principal point of a second lens group closer to the image side than a light entrance surface on the side of the beam splitter of the second lens group and satisfying a specified condition.
CONSTITUTION: A reflection/refraction optical system makes a light beam from a first surface R pass through a first lens group G1 and a beam splitter BS in order, introduces it to a concave mirror M, makes the light beam from the beam splitter BS reflected by the concave mirror M pass through the beam splitter BS and a second lens group G2 in order and introduces it to a second surface W. The rear principal point of the second lens group G2 is located closer to the image side than a light entrance surface on the side of the beam splitter BS and the conditions: $-1<1/\beta M<0.5$. $0.85<L1/f2$ are satisfied, where, βM: the image forming magnification of the concave mirror M, L1: a distance between the rear principal point and the light entrance surface and f2: the focal distance of the second lens group G2.



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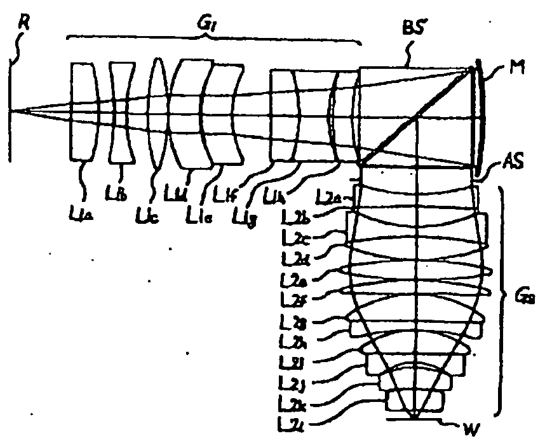
(54)【発明の名称】　反射屈折光学系

(57)【要約】
【目的】　像側における大開口数を達成し、像側作動距離を十分に確保した上でビームスプリッタの小型化を図り、クォーターミクロンの解像を得る。
【構成】　本発明において、第1面Rからの光は、第1レンズ群G_1、ビームスプリッタBS、拡大倍率の凹面鏡M、ビームスプリッタBS及び第2レンズ群G_2の順に通過して第2面W上に達し、第2面W上には第1面Rの縮小像が形成される。本発明は、上述の構成に基づいて凹面鏡Mの結像倍率の好適な範囲と、第2レンズ群G_2の好適な構成とを見出したものである。



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【特許請求の範囲】

【請求項1】第1面の縮小像を第2面上に形成する反射屈折光学系において、

第1レンズ群、ビームスプリッタ、拡大倍率を有する凹面鏡及び第2レンズ群を含み、前記第1面からの光を前記第1レンズ群及び前記ビームスプリッタの順に通過させて前記凹面鏡に導くと共に、前記凹面鏡にて反射された前記ビームスプリッタからの光を前記ビームスプリッタ及び前記第2レンズ群の順に通過させて前記第2面に導き、

前記第2レンズ群の後側主点位置は前記第2レンズ群の前記ビームスプリッタ側の光線入射面位置よりも像側に位置し、

以下の条件を満足することを特徴とする反射屈折光学系。

$-1<1/\beta_M<0.5$

$0.85<L_2/f_2$

但し、β_M ：前記凹面鏡の結像倍率、

L_2 ：前記後側主点位置と前記光線入射面との距離、

f_2 ：前記第2レンズ群の焦点距離、

である。

【請求項2】前記反射屈折光学系全体の結像倍率をβとし、前記第2レンズ群の結像倍率をβ_2とするとき、以下の条件を満足することを特徴とする請求項1記載の反射屈折光学系。

$-1<\beta_2/\beta<1$

【請求項3】前記ビームスプリッタは、プリズム型ビームスプリッタから構成されることを特徴とする請求項1または2記載の反射屈折光学系。

【請求項4】前記プリズム型ビームスプリッタの前記第2レンズ群側の射出面を含む像側には開口絞りが設けられ、以下の条件を満足することを特徴とする請求項3記載の反射屈折光学系。

$0.26<D_1/f_M<1.00$

但し、D_1 ：前記凹面鏡と前記開口絞りとの間の空気換算距離、

f_M ：前記凹面鏡の焦点距離、

である。

【請求項5】前記ビームスプリッタの前記第2レンズ群側の射出面と前記第2面との間の空気換算距離をD_2とし、前記第2レンズ群の焦点距離をf_2とし、前記反射屈折光学系の前記第2面側における開口数をNAとするとき、

以下の条件を満足することを特徴とする請求項4記載の反射屈折光学系。

$D_2 \cdot NA/f_2>0.70$

【請求項6】以下の条件を満足することを特徴とする請求項4または5記載の反射屈折光学系。

$(\phi_0^{1/2}-4d_0 \cdot NA)/(f_2 \cdot (NA)^2)<4$

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但し、ϕ_0 ：前記ビームスプリッタの方向変換面の前記第2レンズ群側の射出面への正射影の面積、

d_0 ：前記反射屈折光学系の前記第2面側における作動距離、

NA：前記反射屈折光学系の前記第2面側における開口数、

f_2 ：前記第2レンズ群の焦点距離、

である。

【請求項7】前記第1及び第2レンズ群は、少なくとも二種類の異なる材質からなる屈折要素から構成され、

前記第1レンズ群は、蛍石からなる負レンズ成分を有し、

前記第2レンズ群は、蛍石からなる正レンズ成分を有することを特徴とする請求項1乃至5のいずれか一項記載の反射屈折光学系。

【発明の詳細な説明】

【0001】

【産業上の利用分野】本発明は、例えば半導体素子、又は液晶表示素子等をフォトリソグラフィ工程で製造する際に使用される投影露光装置用の、縮小投影用の投影光学系に適用して好適な反射屈折縮小光学系に関し、特に光学系の要素として反射系を用いることにより、紫外線波長域でクォーターミクロン単位の解像度を有する反射屈折縮小光学系に関する。

【0002】

【従来の技術】半導体素子等を製造するためのフォトリソグラフィ工程において、フォトマスク又はレチクル（以下、まとめて「レチクル」という）のパターン像を投影光学系を介して例えば1／4乃至1／5程度に縮小して、フォトレジスト等が塗布されたウェハ（又はガラスプレート等）上に露光する投影露光装置が使用されている。半導体素子等の集積度が向上するにつれて、投影露光装置に使用されている投影光学系に要求される解像力は益々高まっている。この要求を満足するために、照明光の波長を短く且つ投影光学系の開口数（N．A．）を大きくする必要が生じている。

【0003】しかしながら、照明光の波長が短くなると、光の吸収によって実用に耐える硝材の種類は限られ、波長が300nm以下になると実用上使える硝材は合成石英と蛍石だけとなる。これにより屈折系だけで投影光学系を構成すると、色収差をはじめ各諸収差補正が困難となる。これに対して反射系は色収差がないため、反射系と屈折系とを組み合わせた所謂反射屈折光学系で縮小投影光学系を構成する技術が提案されている。

【0004】反射系に対する光束の入出力を行うための光路変換用ビームスプリッターを有する反射屈折縮小光学系としては、例えば特開平2－66510号公報、特開平4－235516号公報及び特開平5－72478号公報等に開示されている。ここで、上記公報に開示される反射屈折縮小光学系に含まれている凹面鏡は、すべ

て縮小倍率を持つ収斂鏡であった。

【0005】

【発明が解決しようとする課題】上記の如き従来の反射屈折縮小光学系においては、凹面鏡が縮小倍率を有しているため、凹面鏡よりも像側の光路に配置されるレンズ群の結像倍率が大きなものとなっていた。従って、従来の反射屈折縮小光学系において大きな開口数を得ようとすると、それにほぼ比例してビームスプリッターの口径を大きくする必要がある。これは製造上困難であると共に、製造コストも高くなり過ぎるという不都合がある。そして、凹面鏡が縮小倍率を有しているため、ビームスプリッタから像面までの距離が短くなり、像側における作動距離を十分に確保することが困難である。また、ビームスプリッターの方向変換面に入射する光束の光線の角度が各々違うことによる、結像性能の劣化も避けることが出来ない。

【0006】そこで、本発明は、像側において大きな開口数を達成し、かつ十分な像側作動距離を確保し、さらにビームスプリッタの小型化を図ることができるクォーターミクロン単位の解像をもつ反射屈折光学系を提供することを目的とする。

【0007】

【課題を解決するための手段】上述の目的を達成するために、本発明による反射屈折光学系は、例えば図1に示す如く、第1面Rの縮小像を第2面W上に形成する反射屈折光学系であって、第1レンズ群G_1、ビームスプリッタBS、拡大倍率を有する凹面鏡M及び第2レンズ群G_2を含むように構成される。そして、該反射屈折光学系は、第1面Rからの光を第1レンズ群G_1及びビームスプリッタBSの順に通過させて凹面鏡Mに導くと共に、凹面鏡Mにて反射されたビームスプリッタBSからの光をビームスプリッタBS及び第2レンズ群G_2の順に通過させて第2面Wに導き、第2レンズ群G_2の後側主点位置は第2レンズ群G_2のビームスプリッタBS側の光線入射面位置よりも像側に位置し、以下の条件を満足するように構成される。

【0008】

$-1<1/\beta_M<0.5$ ‥‥(1)

$0.85<L_2/f_2$ ‥‥(2)

但し、β_M：凹面鏡Mの結像倍率、

L_2：後側主点位置と光線入射面との距離、

f_2：第2レンズ群G_2の焦点距離、

である。

【0009】

【作用】上述の構成の如き本発明においては、凹面鏡Mが拡大倍率を有するため、第2レンズ群G_2に大きな正屈折力を持たせることができる。この構成により、ビームスプリッタBSの大型化を図ることなく、像側において大きな開口数を達成し、かつ十分な可動距離を確保することができる。

【0010】そして、本発明においては、ビームスプリッタBS内を通過する光束中の各々の光線の方向変換面への入射角の角度差を小さくできるため、ビームスプリッタBSによる結像性能の劣化を防ぐことができる利点を有する。次に、条件式について詳述する。条件式（1）は凹面鏡Mの好適な結像倍率の範囲についての条件である。この条件式の下限を超えると、第2レンズ群G_2に大きな正屈折力を持たせることが困難となり、像側において大きな開口数を達成するためにはビームスプリッタBS自体の大型化を図る必要が生じる。このときには、ビームスプリッタBSの製造が困難となり、また製造コストの上昇を招く。そして、ビームスプリッタBSと像面との間の距離を十分に確保できなくなるため、十分な作動距離を確保することが困難になる。さらに、凹面鏡MからビームスプリッタBSの方向変換面に向かう光束が収斂光束となるため、この光束中の光線において入射角の角度差が大きくなり、結像性能を低下を招く。なお、この条件式（1）の下限を－0．8とし、$-0.8<1/\beta_M$とすることが好ましい。

【0011】また、条件式（1）の上限を超えると、凹面鏡Mが担っている正の屈折力が小さくなるため、収差補正が困難となる。なお、さらに収差補正を良好とするためには、条件式（1）の上限を0．2とし、$1/\beta_M<0.2$とすることが好ましい。条件式（2）は第2レンズ群G_2の好適な構成についての条件である。ここで、第2レンズ群G_2が条件式（2）を満足しない場合、すなわち条件式（2）の下限を超える場合には、ビームスプリッタBSの径の大型化を免れることができないばかりか、像側における作動距離を実用上十分に確保できなくなるため好ましくない。なお、上記条件式（2）の上限を6．0とし、$L_2/f_2<6.0$とすることが望ましい。この上限値を超える場合には、大きな開口数を得ようとすると、収差補正が困難になるばかりでなく、光学系の全長が長くなり過ぎ、半導体製造装置に用いる投影光学系として不適当である。なお、本発明において、さらに大きな開口数を得ることとビームスプリッタBSの小型化とを考慮すると、条件式（2）の下限値を1．35とし、$1.35<L_2/f_2$とすることが望ましい。

【0012】なお、本発明におけるビームスプリッタBSは、偏光方向によって光を分離する偏光ビームスプリッタであることが好ましい。また、このときには、ビームスプリッタBSと凹面鏡Mとの間の光路中にはλ／4板が配置される。また、本発明においては、第2レンズ群G_2の結像倍率β_2は、本発明の反射屈折光学系全体の結像倍率をβとするとき、以下の条件を満足することが好ましい。

【0013】

$-1<\beta_2/\beta<1$ ‥‥(3)

条件式（3）は、第2レンズ群G_2の結像倍率の好適な

範囲についての条件である。この条件式（3）の下限を超えると、ビームスプリッタＢＳの口径の大型化を伴うことなく、大きな開口数を得ることができなくなるため好ましくない。また、条件式（3）の上限を超えると、本発明の反射屈折光学系における屈折光学要素（例えば第1レンズ群G_1、第2レンズ群G_2）が担う屈折力が大きくなり過ぎ、すなわち反射光学要素（凹面鏡M）の効果が小さくなり、収差補正上において困難を来すため好ましくない。

【0014】本発明においては、ビームスプリッタＢＳをプリズム型ビームスプリッタとすることが好ましい。そして、開口絞りＡＳは、このプリズム型ビームスプリッタの射出面を含む像側に設けられることが好ましい。ここで、開口絞りＡＳは、以下の条件式を満足するように配置されることが好ましい。

$0.26 < D_1 / f_M < 1.00$ …（4）

但し、D_1：凹面鏡Mと開口絞りＡＳとの間の空気換算距離、

f_M：凹面鏡Mの焦点距離、

である。

【0015】ここで、空気換算距離とは、それぞれの媒体の各々の距離と屈折率との商の和として定義される縮小距離であり、空気換算距離をdtとし、媒体の各々の距離をdiとし、各々の媒体の屈折率をniとすると、下式にて表される。

【0016】

【数1】

$$dt = \sum_i \frac{di}{ni}$$

【0017】条件式（4）は、開口絞りＡＳの配置について好適な範囲を定める条件式である。この条件式の下限を超えると、開口絞りＡＳが凹面鏡Mに近づき過ぎる、または凹面鏡Mの焦点距離が長くなり過ぎる。この＊

＊ときには、ビームスプリッタＢＳの小型化を図ることが困難となり、また方向変換面に入射する光線の入射角の角度差を小さくすることが困難となるため好ましくない。ここで、本発明の反射屈折光学系において、上述の条件式（1）および（3）を満足している場合、上記条件式（4）の下限を超えるときには、実用上において十分な像側作動距離を得ることが不可能となるばかりでなく、製造上において開口絞りの配置が困難となるため好ましくない。一方、条件式（4）の上限を超えると、軸外光束の収差、特にコマ収差の補正が困難となるため好ましくない。

【0018】また、本発明の反射屈折光学系は、ビームスプリッタＢＳの第2レンズ群G_2側の射出面と第2面Wとの間の空気換算距離をD_2とし、第2レンズ群G_2の焦点距離をf_2とし、反射屈折光学系の第2面W側における開口数をNAとするとき、以下の条件を満足することが好ましい。

$D_2 \cdot NA / f_2 > 0.70$ …（5）

条件式（5）はビームスプリッターと像面との好適な間隔についての条件式である。この条件式（5）を満足しないと、実用上十分な像側作動距離を保つ場合に、第2レンズ群G_2のためのスペースが小さくなり、第2レンズ群G_2を構成する屈折光学素子の枚数に制限が生じ、収差補正が困難となるため好ましくない。また、条件式（5）を満足しない場合には、上記条件式（3）を満足するように第2レンズ群G_2を構成することが困難となるため好ましくない。なお、大きな像側開口数を達成し、かつ十分な像側作動距離を確保しつつビームスプリッタの小型化を図るためには、条件式（5）における上限を1.0とし、$D_2 \cdot NA / f_2 < 1.0$とすることが望ましい。

【0019】また、本発明においては、以下の条件式（6）を満足するように構成されることが望ましい。

$(\phi_e^{1/2} - 4d_e \cdot NA) / (f_2 \cdot (NA)^2) < 4$ …（6）

但し、ϕ_e：ビームスプリッタＢＳの方向変換面の第2レンズ群G_2側の射出面への正射影の面積、

d_e：反射屈折光学系の第2面W側における作動距離、

NA：反射屈折光学系の第2面W側における開口数、

f_2：第2レンズ群G_2の焦点距離、

である。

【0020】条件式（6）は、像側開口数、像側作動距離及びビームスプリッターの口径に対する第2レンズ群G_2の好適な焦点距離の範囲を定めるための条件式である。この条件式（6）を満足しない場合には、製造上において困難となるため好ましくない。また、ビームスプリッタＢＳの方向変換面上に薄膜を設ける場合やビームスプリッタＢＳにλ／4板を設ける場合においては、ここでの波面収差の発生量が無視できなくなり像の劣化が著しくなるため好ましくない。なお、製造上の容易性を増し、かつ結像性能の向上を図るためには、この条件式（6）の上限を3.5とし、$(\phi_e^{1/2} - 4d_e \cdot NA) / (f_2 \cdot (NA)^2) < 3.5$とすることが望ましい。

【0021】なお、本発明による反射屈折光学系において、300nm以下の波長においてクォーターミクロン単位の解像を満足させつつ色収差を補正するためには、第1レンズ群G_1及び第2レンズ群G_2を少なくとも二種類の異なる材質からなる屈折要素で構成することが好ましい。このとき、第1レンズ群G_1は蛍石からなる負レンズ成分を有し、かつ第2レンズ群は蛍石からなる正レンズ成分を有するように構成されることが望ましい。

【0022】この構成を満足する場合には、蛍石からなる負レンズ成分を有する第1レンズ群G_1によって倍率色収差を補正することが可能となり、蛍石からなる正レンズ成分を有する第2レンズ群G_2によって軸上色収差を補正することができる。また、本発明においては、凹

面鏡Mの倍率を上記条件（1）を満足するように構成しているため、ビームスプリッタＢＳと第２面Ｗとの間に配置される第２レンズ群G_2のためのスペースを十分に確保できる。従って、各レンズ群の屈折要素を上述の如く構成すれば、３００ｎｍ以下の波長においてクォーターミクロン単位の解像を満足しつつ色収差を補正することが可能となる。

【００２３】尚、本発明においては、ビームスプリッタと第２レンズ群との間の光束がアフォーカルな光束とすることが望ましい。また、本発明においては、ビームスプリッタＢＳと凹面鏡Mとの間に、収差補正のためのレンズ群を設けても良い。

【００２４】

【実施例】以下、図面を参照して本発明による各実施例を説明する。図１は、本発明の第１実施例にかかる反射屈折光学系の光学構成を示す光路図である。図１において、図示なき照明光学系は、例えばＡｒＦエキシマレーザの照明光によって、所定のパターンが設けられたレチクルＲを照明する。このレチクルＲからの光は、第１レンズ群G_1を通過した後、ビームスプリッタＢＳの方向変換面を透過し、凹面反射鏡Mにて反射され、再びビームスプリッタＢＳに入射する。凹面反射鏡Mからの光は、ビームスプリッタＢＳの方向変換面にて反射された後に、ビームスプリッタＢＳの射出面側に設けられた開口絞りＡＳを通過して、第２レンズ群G_2を通過し、ウェハＷ上に達する。このウェハＷ上には、レチクルＲの縮小像が形成される。

【００２５】ここで、本実施例においては、ビームスプリッタＢＳは、互いに接合された２つの直角プリズムから構成されている。そして、一方の直角プリズムの斜面上には薄膜が蒸着されている。本実施例では、ビームスプリッタＢＳの接合面上の薄膜が第１レンズ群G_1からの光を透過させ、かつ凹面鏡Mからの光を反射させる機能を有する。

【００２６】次に、図１を参照して第１実施例における各レンズ群のレンズ構成を説明する。第１レンズ群G_1は、物体側から順に、ビームスプリッタＢＳ側により強い凸面を向けた両凸形状の正レンズ成分Ｌ1aと、両凹形状の負レンズ成分Ｌ1bと、両凸形状の正レンズ成分Ｌ1cと、物体側に凸面を向けたメニスカス形状の負レンズ成分Ｌ1dと、同じく物体側に凸面を向けたメニスカス形状の負レンズ成分Ｌ1eと、物体側に凹面を向けたメニスカス形状の正レンズ成分Ｌ1fと、両凹形状の負レンズ成分Ｌ1gと、物体側に凸面を向けたメニスカス形状の負レンズ成分Ｌ1hとから構成される。＊

＊【００２７】また、第２レンズ群G_2は、開口絞りＡＳ側から順に、両凹形状の負レンズ成分Ｌ2aと、両凸形状の正レンズ成分Ｌ2bと、両凹形状の負レンズ成分Ｌ2cと、両凸形状の正レンズ成分Ｌ2dと、両凸形状の正レンズ成分Ｌ2eと、開口絞りＡＳ側により強い凸面を向けた両凸形状の正レンズ成分Ｌ2fと、同じく開口絞りＡＳ側により強い凸面を向けた両凸形状の正レンズ成分Ｌ2gと、開口絞りＡＳ側に凸面を向けたメニスカス形状の負レンズ成分Ｌ2hと、開口絞りＡＳ側に凸面を向けたメニスカス形状の正レンズ成分Ｌ2iと、開口絞りＡＳ側に凸面を向けたメニスカス形状の負レンズ成分Ｌ2jと、開口絞りＡＳ側に凸面を向けたメニスカス形状の正レンズ成分Ｌ2kと、同じく開口絞りＡＳ側に凸面を向けたメニスカス形状の正レンズ成分Ｌ2lとから構成される。

【００２８】以下の表１に本実施例の諸元の値が掲げる。本実施例において、全系の倍率は１／４倍（縮小）であり、ウェハＷ側の開口数ＮＡは０．６であり、ウェハＷ側における作動距離は１５．０ｍｍである。そして、本実施例の反射屈折光学系のウェハＷ上の露光領域を表す平面図である図２に示す如く、第１実施例の反射屈折光学系は、ウェハＷ上における光軸Axからの像高が１５．３ｍｍまでの範囲において３０ｍｍ×６ｍｍのスリット状の露光領域を有する。また、本実施例におけるビームスプリッタＢＳは、１７０ｍｍ×１７０ｍｍ×１９０ｍｍの直方体形状である。

【００２９】また、表１においては、物体面としてのレチクルＲのパターン形成面に相当する第１面から像面としてのウェハＷ面に相当する第２面へ向かう順序で各面の曲率半径ｒ、面間隔ｄおよび硝材を示している。表１中において、各面の曲率半径ｒの符号は、レチクルＲと凹面鏡Mとの間ではレチクルＲ側に凸面を向ける場合を正としており、ビームスプリッタＢＳとウェハＷとの間ではビームスプリッタＢＳ側に凸面を向ける場合を正としている。また、面間隔ｄの符号は、凹面鏡MからビームスプリッタＢＳの方向変換面に到る光路では負にとり、他の光路では正にとる。そして、硝材として、CaF_2は蛍石、SiO_2は石英ガラスをそれぞれ表す。ここで、石英ガラスおよび蛍石の使用基準波長（ＡｒＦレーザの波長：λ＝１９３．４ｎｍ）における屈折率は以下の通りである。

石英ガラス：１．５６０１９

蛍石　　　：１．５０１３８

【００３０】

【表１】〔第１実施例〕

d_0 = 94.539

	r	d	硝材
1	-5313.040	42.330	SiO_2
2	-329.118	23.191	
3	-454.958	18.864	CaF_2

4	272.492	31.123		
5	338.834	31.042	SiO_2	
6	-344.186	0.500		
7	229.022	45.000	SiO_2	
8	184.586	2.298		
9	208.542	45.000	SiO_2	
10	1732.582	56.174		
11	-4435.970	42.860	SiO_2	
12	-244.757	0.500		
13	-288.840	45.000	CaF_2	
14	233.444	5.342		
15	433.000	29.121	SiO_2	
16	268.594	10.042		
17	0.000	170.000	SiO_2	ビームスプリッタＢＳ
18	0.000	10.000		
19	-623.184	-10.000		凹面反射鏡Ｍ
20	0.000	-85.000	SiO_2	
21	0.000	85.000	SiO_2	方向変換面
22	0.000	20.000		
23	0.000	22.917		開口絞りＡＳ
24	-246.212	19.407	SiO_2	
25	1018.290	0.657		
26	1228.970	32.523	CaF_2	
27	-190.064	0.500		
28	-191.929	15.000	SiO_2	
29	424.920	1.933		
30	503.632	37.933	CaF_2	
31	-260.380	0.500		
32	441.375	32.753	CaF_2	
33	-563.177	0.500		
34	378.243	23.321	CaF_2	
35	-13558.170	0.500		
36	152.386	44.866	CaF_2	
37	3098.000	0.500		
38	2231.920	15.006	SiO_2	
39	296.582	0.533		
40	123.151	38.469	CaF_2	
41	7856.190	0.815		
42	7240.660	15.000	SiO_2	
43	74.423	7.394		
44	103.429	35.012	CaF_2	
45	292.945	1.711		
46	192.719	34.643	SiO_2	
47	1452.820	15.000		

以下に第１実施例における条件対応値を示す。

（１）$1/\beta_M = -0.062$

（２）$L_1/f_1 = 1.842$

（３）$\beta_1/\beta = -0.10$

（４）$D_1/f_M = 0.45$

（５）$D_1 \cdot NA/f_1 = 1.37$

（６）$(\phi_M^{1/2} - 4d_0 \cdot NA)/(f_1 \cdot (NA)^2) = 3.03$

図３に第１実施例の横収差図を示す。ここで、図３(a)は像高１０割（像高１５．３ｍｍ）における横収差図であり、図３(b)は像高５割（像高７．６５ｍｍ）における横収差図であり、図３(c)は像高０割（光軸上：像高

０．０ｍｍ）における横収差図である。なお、各横収差図において、実線は基準波長（λ＝ 193.4nm）における収差曲線を表し、点線は波長λ＝ 193.5nmにおける収差曲線、一点鎖線は波長λ＝193.45nmにおける収差曲線、破線はλ＝193.35nmにおける収差曲線、二点鎖線は波長λ＝ 193.3nmにおける収差曲線をそれぞれ表す。図３に示す各横収差図より、本実施例による反射屈折光学系は、ＮＡ＝０．６という非常に大きな開口数を達成しているにも拘わらず、良好に収差が補正され、特に１９３．４ｎｍ±０．１ｎｍでの色収差補正がなされており、優れた結像性能を有していることが分かる。次に図４を参照して本発明による第２実施例を説明する。図４は、本発明の第２実施例による反射屈折光学系の構成を示す光路図である。

【００３１】図４の反射屈折光学系の基本的な構成は、図１に示す第１実施例の反射屈折光学系とほぼ同じであるため、ここでは説明を省略し、各レンズ群のレンズ構成についてのみ説明する。図４において、第１レンズ群G_1は、物体側から順に、物体側に凸面を向けたメニスカス形状の負レンズ成分L_{1a}と、両凸形状の正レンズ成分L_{1b}と、両凸形状の正レンズ成分L_{1c}と、両凹形状の負レンズ成分L_{1d}と、物体側に凹面を向けたメニスカス形状の正レンズ成分L_{1e}と、両凹形状の負レンズ成分L_{1f}と、物体側に凸面を向けたメニスカス形状の負レンズ成分L_{1g}とから構成される。

【００３２】また、第２レンズ群G_2は、開口絞りＡＳ側から順に、両凹形状の負レンズ成分L_{2a}と、両凸形状の正レンズ成分L_{2b}と、両凹形状の負レンズ成分L_{2c}と、両凸形状の正レンズ成分L_{2d}と、同じく両凸形状の正レンズ成分L_{2e}と、開口絞りＡＳ側に凸面を向けたメニスカス形状の正レンズ成分L_{2f}と、開口絞りＡＳ側により強い凸面を向けた両凸形状の正レンズ成分L_{2g}と、開口絞りＡＳ側に凸面を向けたメニスカス形状の負レンズ成分L_{2h}と、開口絞りＡＳ側に凸面を向けたメニスカス＊ ＊ス形状の正レンズ成分L_{2i}と、ウェハＷ側により強い凹面を向けた両凹形状の負レンズ成分L_{2j}と、開口絞りＡＳ側に凸面を向けたメニスカス形状の正レンズ成分L_{2k}と、同じく開口絞りＡＳ側に凸面を向けたメニスカス形状の正レンズ成分L_{2l}とから構成される。以下の表２に本実施例の諸元の値が掲げる。本実施例においては上記第１実施例と同様に、全系の倍率は１／４倍（縮小）であり、ウェハＷ側の開口数ＮＡは０．６であり、ウェハＷ側における作動距離は１５．０ｍｍである。そして、本実施例の反射屈折光学系は、上記第１実施例と同様に、ウェハＷ上における光軸Axからの像高が１５．３ｍｍまでの範囲において３０ｍｍ×６ｍｍのスリット状の露光領域を有する。また、本実施例におけるビームスプリッタＢＳは、１７０ｍｍ×１７０ｍｍ×１９０ｍｍの直方体形状である。

【００３３】また、表２においては、物体面としてのレチクルＲのパターーン形成面に相当する第１面から像面としてのウェハＷ面に相当する第２面へ向かう順序で各面の曲率半径ｒ、面間隔ｄおよび硝材を示している。表２中において、各面の曲率半径ｒの符号は、レチクルＲと凹面鏡Ｍとの間ではレチクルＲ側に凸面を向ける場合を正としており、ビームスプリッタＢＳとウェハＷとの間ではビームスプリッタＢＳ側に凸面を向ける場合を正としている。また、面間隔ｄの符号は、凹面鏡ＭからビームスプリッタＢＳの方向変換面に到る光路では負にとり、他の光路では正にとる。そして、硝材として、CaF_2は蛍石、SiO_2は石英ガラスをそれぞれ表す。ここで、石英ガラスおよび蛍石の使用基準波長（ＡｒＦレーザの波長：λ＝１９３．４ｎｍ）における屈折率は以下の通りである。

石英ガラス：１．５６０１９

蛍石　　　：１．５０１３８

【００３４】

【表２】〔第２実施例〕

d_0 ＝ 111.403

	r	d	硝材
1	5471.605	15.000	CaF_2
2	272.290	2.678	
3	277.567	31.750	SiO_2
4	-278.590	0.500	
5	307.964	38.658	SiO_2
6	-321.548	0.500	
7	-307.926	28.172	CaF_2
8	185.540	116.871	
9	-6054.190	45.000	SiO_2
10	-326.561	3.925	
11	-437.618	18.547	CaF_2
12	429.454	3.774	
13	791.303	28.999	CaF_2
14	197.545	13.348	

15	0.000	170.000	SiO_2	ビームスプリッタBS
16	0.000	10.000		
17	−600.094	−10.000		凹面反射鏡M
18	0.000	−85.000	SiO_2	
19	0.000	85.000	SiO_2	方向変換面
20	0.000	5.000		
21	0.000	18.267		開口絞りAS
22	−228.968	15.000	SiO_2	
23	602.629	1.000		
24	596.556	39.120	CaF_2	
25	−193.759	0.500		
26	−198.735	15.599	SiO_2	
27	414.383	1.371		
28	466.129	43.827	CaF_2	
29	−250.352	0.500		
30	607.920	26.660	CaF_2	
31	−570.532	0.500		
32	319.703	24.752	CaF_2	
33	5248.170	0.500		
34	150.926	44.958	CaF_2	
35	−11154.640	0.500		
36	6931.942	15.000	SiO_2	
37	324.944	0.500		
38	123.172	38.693	CaF_2	
39	27743.950	0.506		
40	−22043.850	15.000	SiO_2	
41	73.840	8.552		
42	103.200	33.698	CaF_2	
43	346.408	1.818		
44	217.213	33.291	SiO_2	
45	1371.742	15.000		

以下に第2実施例における条件対応値を示す。

（1）$1/\beta_M = -0.077$

（2）$L_1/f_1 = 1.924$

（3）$\beta_1/\beta = -0.13$

（4）$D_1/f_M = 0.41$

（5）$D_1 \cdot NA/f_1 = 1.31$

（6）$(\phi_M^{1/2} - 4d_M \cdot NA)/(f_1 \cdot (NA)^2) = 3.09$

図5に第2実施例の横収差図を示す。ここで、図5(a)は像高10割（像高15．3mm）における横収差図であり、図5(b)は像高5割（像高7．65mm）における横収差図であり、図5(c)は像高0割（光軸上：像高0．0mm）における横収差図である。なお、各横収差図において、実線は基準波長（λ＝193.4nm）における収差曲線を表し、点線は波長λ＝193.5nmにおける収差曲線、一点鎖線は波長λ＝193.45nmにおける収差曲線、破線はλ＝193.35nmにおける収差曲線、二点鎖線は波長λ＝193.3nmにおける収差曲線をそれぞれ表す。図5に示す各横収差図より、本実施例による反射屈折光学系は、NA＝0．6という非常に大きな開口数を達成しているにも拘わらず、良好に収差が補正され、特に193．4nm±0．1nmでの色収差補正がなされており、優れた結像性能を有していることが分かる。次に図6を参照して本発明による第3実施例を説明する。図6は、本発明の第2実施例による反射屈折光学系の構成を示す光路図である。

【0035】図6の反射屈折光学系の基本的な構成は、図1に示す第1実施例の反射屈折光学系とほぼ同じであるため、ここでは説明を省略し、各レンズ群のレンズ構成についてのみ説明する。図6において、第1レンズ群G_1は、物体側から順に、ビームスプリッタBS側に強い凸面を向けた両凸形状の正レンズ成分L_{1a}と、両凹形状の負レンズ成分L_{1b}と、両凸形状の正レンズ成分L_{1c}と、物体側に凸面を向けたメニスカス形状の負レンズ成分L_{1d}と、物体側に凸面を向けたメニスカス形状の正レンズ成分L_{1e}と、物体側に凹面を向けたメニスカス形状の正レンズ成分L_{1f}と、両凹形状の負レンズ成分L_{1g}と、物体側に凸面を向けたメニスカス形状の負レンズ成

分Ｌ1hとから構成される。

【００３６】また、第２レンズ群G_2は、開口絞りＡＳ側から順に、両凹形状の負レンズ成分Ｌ2aと、像側に強い凸面を向けた両凸形状の正レンズ成分Ｌ2bと、両凹形状の負レンズ成分Ｌ2cと、像側に強い凸面を向けた両凸形状の正レンズ成分Ｌ2dと、開口絞りＡＳ側に強い凸面を向けた両凸形状の正レンズ成分Ｌ2eと、同じく開口絞りＡＳ側に強い凸面を向けた両凸形状の正レンズ成分Ｌ2fと、同じく開口絞りＡＳ側に強い凸面を向けた両凸形状の正レンズ成分Ｌ2gと、像側に強い凹面を向けた両凹形状の負レンズ成分Ｌ2hと、開口絞りＡＳ側に強い凸面を向けた両凸形状の正レンズ成分Ｌ2iと、開口絞りＡＳ側に凸面を向けたメニスカス形状の負レンズ成分Ｌ2jと、開口絞りＡＳ側に凸面を向けたメニスカス形状の正レンズ成分Ｌ2kと、同じく開口絞りＡＳ側に凸面を向けたメニスカス形状の正レンズ成分Ｌ2lとから構成される。

【００３７】以下の表３に本実施例の諸元の値が掲げる。本実施例においては上記第１実施例と同様に、全系の倍率は１／４倍（縮小）であり、ウェハＷ側の開口数ＮＡは０．６であり、ウェハＷ側における作動距離は１５．０ｍｍである。そして、本実施例の反射屈折光学系は、上記第１実施例と同様に、ウェハＷ上における光軸＊＊Axからの像高が１５．３ｍｍまでの範囲において３０ｍｍ×６ｍｍのスリット状の露光領域を有する。また、本実施例におけるビームスプリッタＢＳは、１７０ｍｍ×１７０ｍｍ×１９０ｍｍの直方体形状である。

【００３８】また、表３においては、物体面としてのレチクルＲのパターン形成面に相当する第１面から像面としてのウェハＷ面に相当する第２面へ向かう順序で各面の曲率半径ｒ、面間隔ｄおよび硝材を示している。表３中において、各面の曲率半径ｒの符号は、レチクルＲと凹面鏡Ｍとの間ではレチクルＲ側に凸面を向ける場合を正としており、ビームスプリッタＢＳとウェハＷとの間ではビームスプリッタＢＳ側に凸面を向ける場合を正としている。また、面間隔ｄの符号は、凹面鏡Ｍからビームスプリッタ ＢＳの方向変換面に到る光路では負にとり、他の光路では正にとる。そして、硝材として、CaF_2は蛍石、SiO_2は石英ガラスをそれぞれ表す。ここで、石英ガラスおよび蛍石の使用基準波長（ＡｒＦレーザの波長：λ＝１９３．４ｎｍ）における屈折率は以下の通りである。石英ガラス：１．５６０１９蛍石：１．５０１３８

【００３９】

【表３】〔第３実施例〕

d_0 = 96.384

	r	d	硝材	
1	1566.352	33.601	SiO_2	
2	−258.445	42.686		
3	−303.358	35.000	CaF_2	
4	254.513	39.688		
5	408.129	35.000	SiO_2	
6	−292.562	0.500		
7	238.980	28.106	SiO_2	
8	177.718	35.520		
9	236.585	35.000	SiO_2	
10	258.786	35.249		
11	−1574.830	35.000	SiO_2	
12	−195.650	0.500		
13	−220.429	25.000	CaF_2	
14	228.713	7.071		
15	380.419	35.000	SiO_2	
16	274.848	10.847		
17	0.000	170.000	SiO_2	ビームスプリッタＢＳ
18	0.000	10.000		
19	−644.053	−10.000		凹面反射鏡Ｍ
20	0.000	−85.000	SiO_2	
21	0.000	85.000	SiO_2	方向変換面
22	0.000	10.000		
23	0.000	16.475		開口絞りＡＳ
24	−240.493	27.541	SiO_2	
25	609.289	0.500		

26	648.361	39.879	CaF_2
27	−161.540	0.500	
28	−161.204	15.000	SiO_2
29	432.174	2.340	
30	513.767	39.791	CaF_2
31	−245.896	0.500	
32	397.672	35.000	CaF_2
33	−1373.400	0.500	
34	350.822	28.205	CaF_2
35	−1504.430	0.500	
36	152.096	44.808	CaF_2
37	−3015.120	0.546	
38	−3831.930	15.302	SiO_2
39	292.927	0.657	
40	122.588	34.934	CaF_2
41	1224.997	0.539	
42	1218.161	15.188	SiO_2
43	74.562	8.605	
44	108.074	35.000	SiO_2
45	377.013	1.406	
46	259.877	35.000	SiO_2
47	767.722	15.000	

以下に第３実施例における条件対応値を示す。

（１）$1/\beta_M = -0.116$

（２）$L_1/f_1 = 2.053$

（３）$\beta_1/\beta = -0.18$

（４）$D_1/f_M = 0.40$

（５）$D_2 \cdot NA/f_2 = 1.37$

（６）$(\phi_M^{1/2} - 4d_M \cdot NA)/(f_2 \cdot (NA)^2) = 3.07$

図７に第３実施例の横収差図を示す。ここで、図７(a)は像高１０割（像高１５．３ｍｍ）における横収差図であり、図７(b)は像高５割（像高７．６５ｍｍ）における横収差図であり、図７(c)は像高０割（光軸上：像高０．０ｍｍ）における横収差図である。なお、各横収差図において、実線は基準波長（λ＝ 193.4nm）における収差曲線を表し、点線は波長λ＝ 193.5nmにおける収差曲線、一点鎖線は波長λ＝193.45nmにおける収差曲線、破線はλ＝193.35nmにおける収差曲線、二点鎖線は波長λ＝ 193.3nmにおける収差曲線をそれぞれ表す。図７に示す各横収差図より、本実施例による反射屈折光学系は、ＮＡ＝０．６という非常に大きな開口数を達成しているにも拘わらず、良好に収差が補正され、特に１９３．４ｎｍ±０．１ｎｍでの色収差補正がなされており、優れた結像性能を有していることが分かる。

【００４０】尚、上述の各実施例において、ビームスプリッタＢＳの方向変換面は、例えば誘電体多層膜からなる偏光分離面であることが好ましい。このときには、ビームスプリッタＢＳの凹面鏡Ｍに対向する面上にλ／４板を設ける。また、上記誘電体多層膜において、収差が発生する場合には、ビームスプリッタＢＳの第１レンズ群G_1に対向する面、凹面鏡Ｍ側に対向する面及び第２レンズ群G_2に対向する面のうちの少なくとも一面に誘電体多層膜にて発生する収差を打ち消す薄膜を設けることが好ましい。このような薄膜としては、例えば厚さまたは屈折率が部分的に異なる構成のものを用いれば良い。

【００４１】また、上述の各実施例においては、第１レンズ群G_1から凹面鏡Ｍに向かう光束がビームスプリッタＢＳの方向変換面を透過し、かつ凹面鏡Ｍから第２レンズ群G_2へ向かう光束がビームスプリッタＢＳの方向変換面にて反射する構成であるが、第１レンズ群G_1からの光束をビームスプリッタＢＳの方向変換面にて反射させて凹面鏡Ｍへ導き、かつ凹面鏡Ｍからの光束をビームスプリッタＢＳの方向変換面を透過させて第２レンズ群G_2へ導く構成としても、光学設計上においては等価なものである。

【００４２】

【発明の効果】以上の通り本発明によれば、像側において大きな開口数を達成し、かつ十分な像側作動距離を確保し、さらにビームスプリッタの小型化を図ることができ、クォーターミクロン単位の解像を達成することができる。

【図面の簡単な説明】

【図１】本発明の第１実施例による反射屈折光学系の光路図である。

【図２】第１実施例の反射屈折光学系の露光領域を示す平面図である。

【図3】第1実施例の横収差図であり、図3(a)は像高10割における横収差図であり、図3(b)は像高5割における横収差図であり、図3(c)は像高0割における横収差図である。

【図4】本発明の第2実施例による反射屈折光学系の光路図である。

【図5】第2実施例の横収差図であり、図5(a)は像高10割における横収差図であり、図5(b)は像高5割における横収差図であり、図5(c)は像高0割における横収差図である。

【図6】本発明の第3実施例による反射屈折光学系の光路図である。＊

＊【図7】第3実施例の横収差図であり、図7(a)は像高10割における横収差図であり、図7(b)は像高5割における横収差図であり、図7(c)は像高0割における横収差図である。

【符号の説明】

G_1… 第1レンズ群、

G_2… 第2レンズ群、

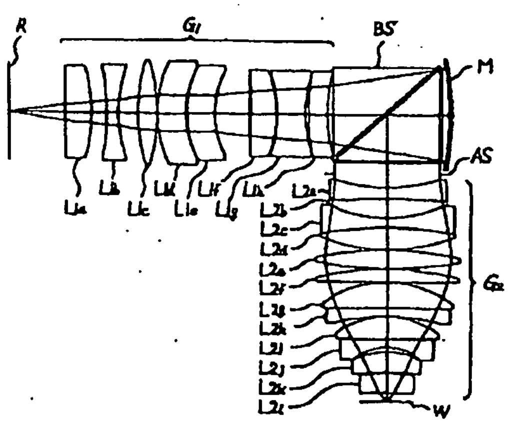
ＢＳ… ビームスプリッタ、

ＡＳ… 開口絞り、

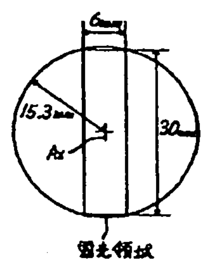
Ｒ … レチクル（第1面）、

Ｗ … ウェハ（第2面）、

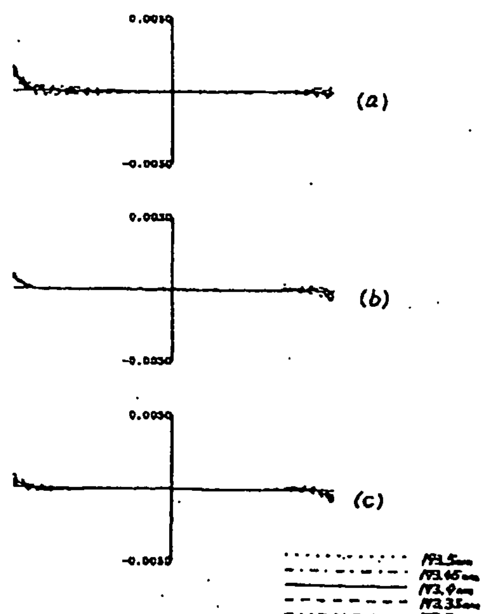
【図1】



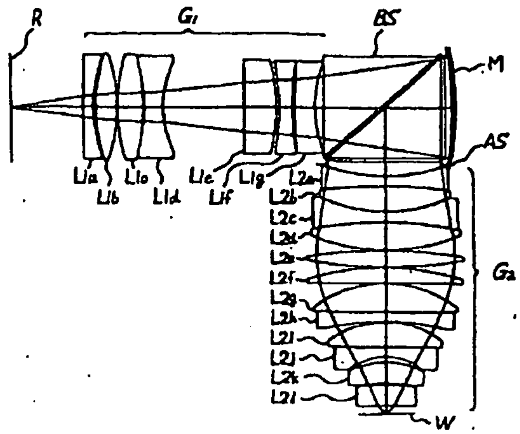
【図2】



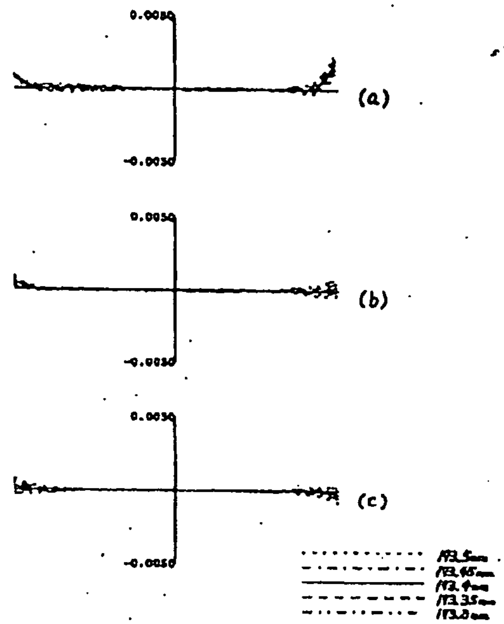
【図3】



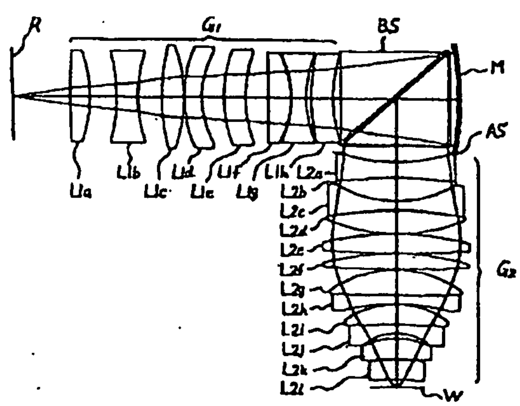
【図4】



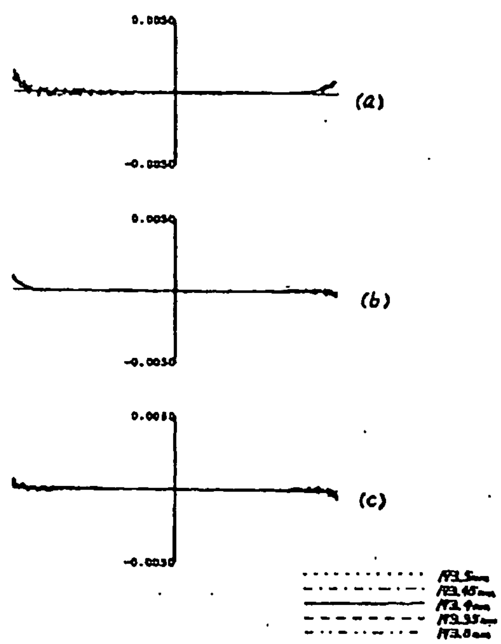
【図5】



【図6】



【図7】



CLAIMS

[Claim(s)]
[Claim 1] In the cata-dioptric system which forms the contraction image of the 1st page on the 2nd page The 1: lens group, While passing said light from the 1st page in order of said 1st lens group and said beam splitter and leading to said concave mirror including the concave mirror and the 2nd lens group which have a beam splitter and magnifying power Pass the light from said beam splitter reflected with said concave mirror in order of said beam splitter and said 2nd lens group, and it leads to said 2nd page. A backside [said 2nd lens group] principa point location is cata-dioptric system characterized by being located in an image side and satisfying the following conditions rather than the beam-of-light plane-of-incidence location by the side of said beam splitter of said 2nd lens group.
- 1 -- < -- 1/betaM <0.50.85 -- < -- L1 / f2, however betaM : The image formation scale factor of said concave mirror, and L1 : The distance of said backside principal point location and said beam-of-light plane of incidence, and f2 : the focal distance of said 2nd lens group -- it comes out.
[Claim 2] the image formation scale factor of said whole cata-dioptric system -- beta -- carrying out -- the imag formation scale factor of said 2nd lens group -- beta 2 ** -- cata-dioptric system according to claim 1 characterized by satisfying the following conditions when carrying out.
- 1 -- < -- beta 2 / beta< 1 -- [Claim 3] Said beam splitter is cata-dioptric system according to claim 1 or 2 characterized by consisting of prism mold beam splitters.
[Claim 4] Cata-dioptric system according to claim 3 characterized by preparing an aperture diaphragm in an image side including the injection side by the side of said 2nd lens group of said prism mold beam splitter, and satisfying the following conditions.
0.26<D1/fM <1.00, however D1 : The air scaled distance between said concave mirrors and said aperture diaphragms, and fM : the focal distance of said concave mirror -- it comes out.
[Claim 5] It is the air scaled distance between the injection side by the side of said 2nd lens group of said beam splitter, and said 2nd page D2 It carries out and is the focal distance of said 2nd lens group f2 Cata-dioptric system according to claim 4 characterized by satisfying the following conditions when carrying out and setting numerical aperture by the side of said 2nd page of said cata-dioptric system to NA.
D2 and NA/f 2 > 0.70 -- [Claim 6] Cata-dioptric system according to claim 4 or 5 characterized by satisfying the following conditions.
(phiB 1/2-4dW and NA)/(f2 and 2) <4 -- however phiB : Area of the orthographic projection to the injection side by the side of said 2nd lens group of the directional change side of said beam splitter, dW : -- the working distance by the side of said 2nd page of said cata-dioptric system, and NA: -- the numerical aperture by the sid of said 2nd page of said cata-dioptric system, and f2 : the focal distance of said 2nd lens group -- it comes out.
[Claim 7] It is the cata-dioptric system of five claim 1 characterized by for said 1st and 2nd lens group consisting of refraction elements which consist of at least two kinds of different quality of the materials, for sai 1st lens group having the negative lens component which consists of fluorite, and said 2nd lens group having the positive lens component which consists of fluorite thru/or given in any 1 term.

[Translation done.]

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1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application] It is related with the reflective refraction contraction optical system which has the resolution of a quarter micron unit in an ultraviolet-rays wavelength region by applying to the projection optic for contraction projection for the projection aligners used in case this invention is manufactured by the semiconductor device and ** manufactures a liquid crystal display component etc. at a photolithography process, and using a reflective system especially as an element of optical system about suitable reflective refraction contraction optical system.
[0002]
[Description of the Prior Art] In the photolithography process for manufacturing a semiconductor device etc., photo mask or the pattern image of a reticle (collectively henceforth a "reticle") is reduced to 1/4 thru/or about 1/5 through projection optics, and the projection aligner exposed on the wafer (** is a glass plate etc.) with which the photoresist etc. was applied is used. The resolution required of the projection optics currently used f the projection aligner is increasing increasingly as degrees of integration, such as a semiconductor device, improve. In order to satisfy this demand, it will be necessary to enlarge numerical aperture (N.A.) of projectioi optics short [wavelength / of the illumination light].
[0003] However, if the wavelength of the illumination light becomes short, the class of ** material which is equal to practical use with the absorption of light will be restricted, and if wavelength is set to 300nm or less, the ** material which can be used practically will serve as only synthetic quartz and fluorite. If this constitutes projection optics only from refractive media, chromatic aberration will be begun and each ****** amendment will become difficult. On the other hand, since a reflective system does not have chromatic aberration, the technique which constitutes contraction projection optics from so-called cata-dioptric system which combined reflective system and refractive media is proposed.
[0004] As reflective refraction contraction optical system which has a beam splitter for optical-path conversioi for outputting and inputting the flux of light over a reflective system, it is indicated by JP,2-66510,A, JP,4-235516,A, JP,5-72478,A, etc., for example. All the concave mirrors contained in the reflective refraction contraction optical system indicated by the above-mentioned official report here were convergence mirrors wi a contraction scale factor.
[0005]
[Problem(s) to be Solved by the Invention] In the conventional reflective refraction contraction optical system like the above, since the concave mirror had the contraction scale factor, it had become what has the bigger image formation scale factor of the lens group arranged at the optical path by the side of an image than a concave mirror. Therefore, if it is going to obtain a big numerical aperture in the conventional reflective refraction contraction optical system, it is necessary to enlarge aperture of a beam splitter in proportion [almost] to it. Having un-arranged [that a manufacturing cost also becomes high too much] while a manufacture top is difficult for this. And since the concave mirror has the contraction scale factor, it is difficul for the distance from a beam splitter to the image surface to become short, and to fully secure the working distance by the side of an image. Moreover, degradation of the image formation engine performance by the include angle of the beam of light of the flux of light which carries out incidence to the directional change side of a beam splitter being respectively different is also unavoidable.
[0006] Then, a big numerical aperture is attained, and this invention secures sufficient image side working

distance to an image side, and aims at offering cata-dioptric system with resolving of a quarter micron unit which can attain the miniaturization of a beam splitter further.

[0007]

[Means for Solving the Problem] The cata-dioptric system according to this invention in order to attain the above-mentioned purpose is the concave mirror M and the 2nd lens group G2 which are the cata-dioptric system which forms the contraction image of the 1st page R on the 2nd page W, and have the 1st lens group (a beam splitter BS, and magnifying power as shown in drawing 1 . It is constituted so that it may contain. An this cata-dioptric system is the 1st lens group G1 about the light from the 1st page R. And while making it pa: in order of a beam splitter BS and leading to a concave mirror M They are a beam splitter BS and the 2nd len: group G2 about the light from the beam splitter BS reflected with the concave mirror M. Make it pass in orde and it leads to the 2nd page W. The 2nd lens group G2 A backside principal point location is the 2nd lens gro G2. It is located in an image side rather than the beam-of-light plane-of-incidence location by the side of a be: splitter BS, and it is constituted so that the following conditions may be satisfied.

[0008]

- 1<1/betaM <0.5 .... (1)

0.85<L1 / f2 .... (2)

however, betaM : The image formation scale factor of a concave mirror M, and L1 : The distance of a backsic principal point location and beam-of-light plane of incidence, and f2 : The 2nd lens group G2 a focal distance it comes out.

[0009]

[Function] Since a concave mirror M has magnifying power in this invention like an above-mentioned configuration, it is the 2nd lens group G2. Forward big refractive power can be given. By this configuration, without attaining enlargement of a beam splitter BS, big numerical aperture can be attained and sufficient movable distance can be secured to an image side.

[0010] And in this invention, since angular difference of the angle of incidence to the directional change side each beam of light in the flux of light which passes through the inside of a beam splitter BS can be made smal it has the advantage which can prevent degradation of the image formation engine performance by the beam splitter BS. Next, conditional expression is explained in full detail. Conditional expression (1) is the condition about the range of the suitable image formation scale factor of a concave mirror M. When the minimum of thi conditional expression is exceeded, it is the 2nd lens group G2. It becomes difficult to give forward big refractive power, and in order to attain a big numerical aperture to an image side, it will be necessary to attain enlargement of beam splitter BS itself. At this time, manufacture of a beam splitter BS becomes difficult, and the rise of a manufacturing cost is caused. And since it becomes impossible to fully secure the distance betwe a beam splitter BS and the image surface, it becomes difficult to secure sufficient working distance. Furthermore, since the flux of light which goes to the directional change side of a beam splitter BS turns into the convergence flux of light from a concave mirror M, in the beam of light in this flux of light, the angular difference of an incident angle becomes large and causes a fall for the image formation engine performance. I addition, the minimum of this conditional expression (1) is set to -0.8, and it is -0.8<1/betaM. Carrying out is desirable.

[0011] Moreover, if the upper limit of conditional expression (1) is exceeded, since the forward refractive power which the concave mirror M is bearing will become small, aberration amendment becomes difficult. In addition, in order to make aberration amendment good further, it is desirable to set the upper limit of conditional expression (1) to 0.2, and to be referred to as 1/betaM <0.2. Conditional expression (2) is the 2nd lens group G2. They are the conditions about a suitable configuration. Here, it is the 2nd lens group G2. Whe not satisfying conditional expression (2) (i.e., when exceeding the minimum of conditional expression (2)), since it becomes impossible to fully secure practically the working distance by the side of about [that enlargement of the path of a beam splitter BS cannot be escaped], and an image, it is not desirable. In additio it is desirable to set the upper limit of the above-mentioned conditional expression (2) to 6.0, and to be referre to as L1/f2 <6.0. If it is going to obtain big numerical aperture when exceeding this upper limit, it is unsuitabl as projection optics aberration amendment not only becomes difficult, but used for semiconductor fabrication machines and equipment by the overall length of optical system becoming long too much. In addition, when obtaining a still bigger numerical aperture and the miniaturization of a beam splitter BS are taken into

consideration in this invention, the lower limit of conditional expression (2) is set to 1.35, and it is 1.35<L1 / f2 Carrying out is desirable.

[0012] In addition, as for the beam splitter BS in this invention, it is desirable that it is the polarization beam splitter which separates light according to the polarization direction. Moreover, at this time, lambda/4 plate is arranged in the optical path between a beam splitter BS and a concave mirror M. Moreover, it sets to this invention and is the 2nd lens group G2. Image formation scale factor beta 2 When setting the image formation scale factor of the whole cata-dioptric system of this invention to beta, it is desirable to satisfy the following conditions.

[0013]

- 1<beta2 / beta< 1 -- (3)

Conditional expression (3) is the 2nd lens group G2. They are the conditions about the range where an image formation scale factor is suitable. Without being accompanied by enlargement of the aperture of a beam splitter BS, if the minimum of this conditional expression (3) is exceeded, since it becomes impossible to obtain big numerical aperture, it is not desirable. Moreover, if the upper limit of conditional expression (3) is exceeded, it is not desirable in order for the refractive power which the dioptrics element (for example, the 1st lens group G and the 2nd lens group G2) in the cata-dioptric system of this invention bears to become large too much, namely, for the effectiveness of a reflected light study element (concave mirror M) to become small and to cause difficulty on aberration amendment.

[0014] In this invention, it is desirable to make a beam splitter BS into a prism mold beam splitter. And as for aperture diaphragm AS, it is desirable to be prepared in an image side including the injection side of this prism mold beam splitter. Here, as for aperture-diaphragm AS, it is desirable to be arranged so that the following conditional expression may be satisfied.

0.26<D1/fM <1.00 -- (4)

D1 [however,] : The air scaled distance between a concave mirror M and aperture-diaphragm AS, and fM : the focal distance of a concave mirror M -- it comes out.

[0015] Here, air scaled distance is a contraction distance defined as the sum of the quotient of each distance and refractive index of each medium, and is dt about air scaled distance. It carries out and is di about each distance of a medium. It carries out and is ni about the refractive index of each medium. It is expressed with a bottom type when carrying out.

[0016]

[Equation 1]

$$dt = \sum_i \frac{di}{ni}$$

[0017] Conditional expression (4) is conditional expression by which the range suitable about arrangement of aperture-diaphragm AS is provided. If the minimum of this conditional expression is exceeded, aperture-diaphragm AS will approach a concave mirror M too much, or the focal distance of a concave mirror M will become long too much. Since it becomes difficult to make small angular difference of the incident angle of the beam of light which it becomes difficult at this time to attain the miniaturization of a beam splitter BS, and carries out incidence to a directional change side, it is not desirable. When above-mentioned conditional expression (1) and (3) are satisfied and the minimum of the above-mentioned conditional expression (4) is exceeded in the cata-dioptric system of this invention here, since it not only becomes impossible to acquire sufficient image side working distance on practical use, but arrangement of an aperture diaphragm becomes difficult on manufacture, it is not desirable. On the other hand, if the upper limit of conditional expression (4) is exceeded, since amendment of the aberration of an axial outdoor daylight bundle, especially comatic aberration becomes difficult, it is not desirable.

[0018] Moreover, the cata-dioptric system of this invention is the air scaled distance between the injection side by the side of the 2nd lens group G2 of a beam splitter BS, and the 2nd page W D2 It carries out and is the 2nd lens group G2. It is a focal distance f2 When carrying out and setting numerical aperture by the side of the 2nd page W of cata-dioptric system to NA, it is desirable to satisfy the following conditions.

D2 and NA/f 2 > 0.70 -- (5)

Conditional expression (5) is the conditional expression about suitable spacing of a beam splitter and the image surface. If this conditional expression (5) is not satisfied, when maintaining practically sufficient image side

working distance, it is the 2nd lens group G2. The tooth space of a sake becomes small and it is the 2nd lens group G2. Since a limit arises in the number of sheets of the dioptrics component to constitute and aberration amendment becomes difficult, it is not desirable. Moreover, it is the 2nd lens group G2 so that it may satisfy tl above-mentioned conditional expression (3), in not satisfying conditional expression (5). Since constituting becomes difficult, it is not desirable. In addition, in order to attain the miniaturization of a beam splitter, attaining a big image side numerical aperture, and securing sufficient image side working distance, it is desirable to set the upper limit in conditional expression (5) to 1.0, and to consider as D2 and NA/f 2 < 1.0.

[0019] Moreover, in this invention, it is desirable to be constituted so that the following conditional expressioı (6) may be satisfied.

(phiB 1/2-4dW and NA)/(f2 and 2) <4 -- (6)

however, phiB : The 2nd lens group G2 of the directional change side of a beam splitter BS The area of the orthographic projection to a near injection side, and dW : The working distance by the side of the 2nd page W of cata-dioptric system, the numerical aperture by the side of the 2nd page W of NA:cata-dioptric system, and f2 : The 2nd lens group G2 a focal distance -- it comes out.

[0020] Conditional expression (6) is an image side numerical aperture, the image side working distance, and tl 2nd lens group G2 to the aperture of a beam splitter. It is the conditional expression for appointing the range o a suitable focal distance. When not satisfying this conditional expression (6), since it becomes difficult on manufacture, it is not desirable. Moreover, since it becomes impossible to disregard the yield of wave aberratic here and degradation of an image becomes remarkable when forming lambda/4 plate in the case where a thin film is prepared on the directional change side of a beam splitter BS, or a beam splitter BS, it is not desirable.] addition, in order to aim at improvement in the increase of ease and the image formation engine performance c manufacture, it is desirable to set the upper limit of this conditional expression (6) to 3.5, and to be referred to as (phiB 1/2-4dW and NA)/(f2 and 2) <3.5.

[0021] In addition, in order to amend chromatic aberration in the cata-dioptric system by this invention, satisfying resolving of a quarter micron unit in the wavelength of 300nm or less, it is the 1st lens group G1. Ar the 2nd lens group G2 It is desirable to constitute from a refraction element which consists of at least two kind of different quality of the materials. At this time, it is the 1st lens group G1. It has the negative lens componen which consists of fluorite, and, as for the 2nd lens group, it is desirable to be constituted so that it may have th positive lens component which consists of fluorite.

[0022] The 1st lens group G1 which has the negative lens component which consists of fluorite in satisfying this configuration The 2nd lens group G2 which has the positive lens component which becomes possible [amending the chromatic aberration of magnification], and consists of fluorite Axial overtone aberration can be amended. Moreover, the 2nd lens group G2 arranged between a beam splitter BS and the 2nd page W since the scale factor of a concave mirror M is constituted in this invention so that the above-mentioned conditions (1) may be satisfied The tooth space of a sake is fully securable. Therefore, if the refraction element of each le group is constituted like ****, it will become possible to amend chromatic aberration, satisfying resolving of a quarter micron unit in the wavelength of 300nm or less.

[0023] In addition, in this invention, it is desirable for the flux of light between a beam splitter and the 2nd len group to consider as the afocal flux of light. Moreover, in this invention, the lens group for aberration amendment may be prepared between a beam splitter BS and a concave mirror M.

[0024]

[Example] Hereafter, each example by this invention is explained with reference to a drawing. Drawing 1 is th optical-path Fig. showing the optical configuration of the cata-dioptric system concerning the 1st example of this invention. In drawing 1 , the illumination-light study system without illustration illuminates the reticle R i which the predetermined pattern was prepared by the illumination light of for example, ArF excimer laser. Th light from this reticle R is the 1st lens group G1. After passing, the directional change side of a beam splitter B is penetrated, it is reflected by Lieberkuhn M, and incidence is again carried out to a beam splitter BS. The lig from Lieberkuhn M passes aperture-diaphragm AS prepared in the injection side side of a beam splitter BS aft being reflected in respect of directional change of a beam splitter BS, and is the 2nd lens group G2. It passes and reaches on Wafer W. The contraction image of Reticle R is formed on this wafer W.

[0025] Here, in this example, the beam splitter BS consists of two joined rectangular prisms. And the thin film is vapor-deposited on the slant face of one rectangular prism. this example -- the thin film on the plane of

composition of a beam splitter BS -- the 1st lens group G1 from -- it has the function to make light penetrate and to reflect the light from a concave mirror M.
[0026] Next, with reference to drawing 1, the lens configuration of each lens group in the 1st example is explained. The 1st lens group G1 Positive lens component L1a of both the convex configuration which turne the strong convex by the beam splitter BS side sequentially from the body side, Negative lens component L1l of both the concave configuration, and positive lens component L1c of both the convex configuration, Negati lens component L1d of the meniscus configuration where the convex was turned to the body side, and negati lens component L1e of a meniscus configuration which similarly turned the convex to the body side, It consi of positive lens component L1f of the meniscus configuration where the concave surface was turned to the b side, negative lens component L1g of both the concave configuration, and negative lens component L1h of th meniscus configuration where the convex was turned to the body side.
[0027] Moreover, the 2nd lens group G2 Sequentially from the aperture-diaphragm AS side, negative lens component L2a of both the concave configuration, Positive lens component L2b of both the convex configuration, and negative lens component L2c of both the concave configuration, Positive lens component L2d of both the convex configuration, and positive lens component L2e of both the convex configuration, Positive lens component L2f of both the convex configuration where the strong convex was turned by the aperture-diaphragm AS side, Positive lens component L2g of both the convex configuration where the strong convex was similarly turned by the aperture-diaphragm AS side, Negative lens component L2h of the menisc configuration where the convex was turned to the aperture-diaphragm AS side, Positive lens component L2i (a meniscus configuration which turned the convex to the aperture-diaphragm AS side, It consists of negative lens component L2j of a meniscus configuration which turned the convex to the aperture-diaphragm AS side, positive lens component L2k of a meniscus configuration which turned the convex to the aperture-diaphragm AS side, and positive lens component L2l. of the meniscus configuration where the convex was similarly turr to the aperture-diaphragm AS side.
[0028] The value of the item of this example hangs up over following Table 1. In this example, it is 1/4 time (contraction) the scale factor of the whole system of this, and the numerical aperture NA by the side of Wafe W is 0.6, and the working distance by the side of Wafer W is 15.0mm. And as shown in drawing 2 which is a top view showing the exposure field on the wafer W of the cata-dioptric system of this example, the image quantity from the optical axis [cata-dioptric system / of the 1st example] Ax on Wafer W has the exposure field of the shape of a 30mmx6mm slit in the range to 15.3mm. Moreover, the beam splitter BS in this examp is a 170mmx170mmx190mm rectangular parallelepiped configuration.
[0029] Moreover, in Table 1, the sequence of going to the 2nd page equivalent to the Wth page of the wafer a the image surface from the 1st page equivalent to the pattern formation side of the reticle R as a body side shows the radius of curvature r, Spacing d, and the ** material of each side. All over Table 1, between Reticl and the concave mirror M, the sign of the radius of curvature r of each field makes forward the case where a convex is turned at Reticle R side, and makes forward the case where a convex is turned at a beam splitter BS side, between the beam splitter BS and Wafer W. Moreover, the sign of Spacing d is just taken by other optic paths for negative according to the optical path which reaches the directional change side of a beam splitter B from a concave mirror M. And it is CaF2 as ** material. Fluorite and SiO2 Quartz glass is expressed, respectively. Here, the refractive index in the criteria-for-use-of-food-additives wavelength (wavelength of A laser: lambda= 193.4nm) of quartz glass and fluorite is as follows.
Quartz glass: 1.56019 fluorite : 1.50138 [0030]
[Table 1] [The 1st example]
d0 = 94.539 r d ** material 1 -5313.040 42.330 SiO2 2 - 329.118 23.191 3 - 454.958 18.864 CaF2 4 272.492 31.123 5 338.834 31.042 SiO2 6 - 344.186 0.500 7 229.022 45.000 SiO2 8 184.586 2.298 9 208.542 45.000 SiO2 10 1732. 582 56.174 11 -4435.970 42.860SiO2 12 - 244.757 0.50013 -288.84045.000CaF2 14233.444 5.342 15 433.000 29.121 SiO2 16 268.594 10.04217 0.000 170.000 SiO2 Beam splitter BS 18 0.000 10.000 1 623.184 -10.000 The lieberkuhn M20 0.000-85.000 SiO2 21 0.000 85.000 SiO2 Directional change side 22 0.000 20.000 23 0.00022.917 Aperture-diaphragm AS24 - 246.212 19.407 SiO2 25 1018. 290 0.657 26 1228. 970 32.523 CaF2 27 -190.064 0.500 28 - 191.929 15.000SiO2 29 424.920 1.933 30 503.632 37.933 CaF2 31 260.380 0.500 32 441.375 32.753 CaF2 33 -563.177 0.500 34378.243 23.321CaF2 35 -13558.170 0.500 36 152.386 44.866 CaF2 37 3098. 000 0.500 38 2231.92015.006 SiO2 39 296.582 0.533 40 123.15138.469CaF2

417856.190 0.815 42 7240. 660 15.000SiO2 43 74.4237.394 44 103.42935.012CaF2 45 292.945 1.711 46 192.71934.643 SiO2 471452.820 15.000 The value corresponding to conditions in the 1st example is shown below.
(1) 1/betaM =-0.062(2) L1 /-- f -- two -- = -- 1.842 -- (-- three --) -- beta -- two -- /-- beta -- = - 0.10 -- (-- four) -- D -- one -- /-- fM -- = -- 0.45 -- (-- five --) -- D -- two - NA/f -- two -- = -- 1.37 -- (-- six --) -- (-- phi -- B -- one -- /-- two - four -- dW - NA --) -- /(f2 and 2) -- = -- 3.03 -- drawing 3 -- the transverse aberration Fig. of th 1st example -- being shown -- . Here, it is drawing 3 (a). It is a transverse aberration Fig. in one hundred perce (15.3mm of image quantities) of image quantities, and is drawing 3 (b). It is a transverse aberration Fig. in 50 percent (7.65mm of image quantities) of image quantities, and is drawing 3 (c). It is a transverse aberration Fi in 0 percent (on an optical axis: 0.0mm of image quantities) of image quantities. In addition, in each transvers aberration Fig., a continuous line expresses the aberration curve in criteria wavelength (lambda = 193.4nm), a an aberration curve [in / in a dotted line / lambda= 193.5 nm wavelength], an aberration curve [in / in an alternate long and short dash line / the wavelength of lambda= 193.45nm], an aberration curve [in / in a brok line / lambda= 193.35nm], and a two-dot chain line express the aberration curve in lambda= 193.3 nm wavelength, respectively. Each transverse aberration Fig. shown in drawing 3 shows that the cata-dioptric system by this example has the image formation engine performance of NA=0.6 which the chromatic-aberrati amendment by 193.4nm**0.1nm is especially made by amending aberration good in spite of having attained b numerical aperture very much, and was excellent. Next, the 2nd example by this invention is explained with reference to drawing 4 R> 4. Drawing 4 is the optical-path Fig. showing the configuration of the cata-dioptric system by the 2nd example of this invention.
[0031] Since the fundamental configuration of the cata-dioptric system of drawing 4 is almost the same as the cata-dioptric system of the 1st example shown in drawing 1 , it omits explanation here and explains only the lens configuration of each lens group. It sets to drawing 4 and is the 1st lens group G1. Negative lens component L1a of a meniscus configuration which turned the convex to the body side sequentially from the body side, Positive lens component L1b of both the convex configuration, and positive lens component L1c o both the convex configuration, It consists of positive lens component L1e of a meniscus configuration which turned the concave surface to the negative lens component L1d and body side of both the concave configuration, negative lens component L1f of both the concave configuration, and negative lens component L1g of the meniscus configuration where the convex was turned to the body side.
[0032] Moreover, the 2nd lens group G2 Sequentially from the aperture-diaphragm AS side, negative lens component L2a of both the concave configuration, Positive lens component L2b of both the convex configuration, and negative lens component L2c of both the concave configuration, As well as positive lens component L2d of both the convex configuration, positive lens component L2e of both the convex configuration, Positive lens component L2f of the meniscus configuration where the convex was turned to the aperture-diaphragm AS side, Positive lens component L2g of both the convex configuration where the strong convex was turned by the aperture-diaphragm AS side, Negative lens component L2h of the meniscus configuration where the convex was turned to the aperture-diaphragm AS side, Positive lens component L2i o a meniscus configuration which turned the convex to the aperture-diaphragm AS side, It consists of negative lens component L2j of both the concave configuration which turned the strong concave surface by Wafer W side, positive lens component L2k of a meniscus configuration which turned the convex to the aperture-diaphragm AS side, and positive lens component L2l. of the meniscus configuration where the convex was similarly turned to the aperture-diaphragm AS side. The value of the item of this example hangs up over following Table 2. In this example, it is 1/4 time (contraction) the scale factor of the whole system of this like the 1st example of the above, and the numerical aperture NA by the side of Wafer W is 0.6, and the working distance by the side of Wafer W is 15.0mm. And as for the cata-dioptric system of this example, the image quantity from the optical axis Ax on Wafer W has the exposure field of the shape of a 30mmx6mm slit in the range to 15.3mm like the 1st example of the above. Moreover, the beam splitter BS in this example is a 170mmx170mmx190mm rectangular parallelepiped configuration.
[0033] Moreover, in Table 2, the sequence of going to the 2nd page equivalent to the Wth page of the wafer as the image surface from the 1st page equivalent to the pattern formation side of the reticle R as a body side shows the radius of curvature r, Spacing d, and the ** material of each side. All over Table 2, between Reticle and the concave mirror M, the sign of the radius of curvature r of each field makes forward the case where a

convex is turned at Reticle R side, and makes forward the case where a convex is turned at a beam splitter BS side, between the beam splitter BS and Wafer W. Moreover, the sign of Spacing d is just taken by other optical paths for negative according to the optical path which reaches the directional change side of a beam splitter BS from a concave mirror M. And it is CaF2 as ** material. Fluorite and SiO2 Quartz glass is expressed, respectively. Here, the refractive index in the criteria-for-use-of-food-additives wavelength (wavelength of ArF laser: lambda= 193.4nm) of quartz glass and fluorite is as follows.
Quartz glass: 1.56019 fluorite : 1.50138 [0034]
[Table 2] [The 2nd example]
d0 = 111.403 r d ** material 1 5471. 605 15.000 CaF2 2 272.290 2.678 3 277.567 31.750 SiO2 4 - 278.590 0.500 5 307.964 38.658 SiO2 6 - 321.548 0.500 7 - 307.926 28.172 CaF2 8 185.540 116.871 9 -6054.190 45.000 SiO2 10 - 326.561 3.925 11 - 437.618 18.547CaF2 12 429.454 3.774 13 791.30328.999 CaF2 14197.545 13.34815 0.000170.000 SiO2 Beam splitter BS16 0.000 10.000 17 -600.094 -10.000 The lieberkuhn M18 0.000 -85.000 SiO2 19 0.00085.000 SiO2 The directional change side 20 0.000 5.000 21 0.000 18.267 Aperture-diaphragm AS22 - 228.968 15.000 SiO2 23 602.629 1.000 24 596.556 39.120 CaF2 25-193.7590.50(26-198.735 15.599 SiO2 27 414.383 1.371 28 466.129 43.827CaF2 29 -250.352 0.500 30 607.920 26.660 CaF 31-570.532 0.500 32 319.703 24.752 CaF2 33 5248.170 0.50034 150.926 44.958 CaF2 35 -11154.640 0.5003(6931.942 15.000 SiO2 37 324.944 0.500 38 123.172 38.693 CaF2 3927743.950 0.506 40 -22043.850 15.000 SiO2 41 73.840 8.55242 103.200 33.698CaF2 43 346.408 1.818 44 217.213 33.291SiO2 45 1371.742 15.000
The value corresponding to conditions in the 2nd example is shown below.
(1) 1/betaM =-0.077(2) L1 /-- f -- two -- = -- 1.924 -- (-- three --) -- beta -- two -- /-- beta -- = - 0.13 -- (-- four --) -- D -- one -- /-- fM -- = -- 0.41 -- (-- five --) -- D -- two - NA/f -- two -- = -- 1.31 -- (-- six --) -- (-- phi -- B -- one -- /-- two - four -- dW - NA --) -- /(f2 and 2) -- = -- 3.09 -- drawing 5 -- the transverse aberration Fig. of the 2nd example -- being shown -- . Here, it is drawing 5 (a). It is a transverse aberration Fig. in one hundred percent (15.3mm of image quantities) of image quantities, and is drawing 5 (b). It is a transverse aberration Fig in 50 percent (7.65mm of image quantities) of image quantities, and is drawing 5 (c). It is a transverse aberration Fig. in 0 percent (on an optical axis: 0.0mm of image quantities) of image quantities. In addition, in each transverse aberration Fig., a continuous line expresses the aberration curve in criteria wavelength (lambda = 193.4nm), and an aberration curve [in / in a dotted line / lambda= 193.5 nm wavelength], an aberration curv [in / in an alternate long and short dash line / the wavelength of lambda= 193.45nm], an aberration curve [in in a broken line / lambda= 193.35nm], and a two-dot chain line express the aberration curve in lambda= 193.3 nm wavelength, respectively. Each transverse aberration Fig. shown in drawing 5 shows that the cata-dioptric system by this example has the image formation engine performance of NA=0.6 which the chromatic-aberratic amendment by 193.4nm**0.1nm is especially made by amending aberration good in spite of having attained b numerical aperture very much, and was excellent. Next, the 3rd example by this invention is explained with reference to drawing 6 R> 6. Drawing 6 is the optical-path Fig. showing the configuration of the cata-dioptric system by the 2nd example of this invention.
[0035] Since the fundamental configuration of the cata-dioptric system of drawing 6 is almost the same as the cata-dioptric system of the 1st example shown in drawing 1 , it omits explanation here and explains only the lens configuration of each lens group. It sets to drawing 6 and is the 1st lens group G1. Positive lens componer L1a of both the convex configuration which turned the convex strong against a beam splitter BS side sequentially from the body side, Negative lens component L1b of both the concave configuration, and positive lens component L1c of both the convex configuration, Positive lens component L1e of a meniscus configuratic which turned the convex to the negative lens component L1d and body side of the meniscus configuration where the convex was turned to the body side, It consists of positive lens component L1f of the meniscus configuration where the concave surface was turned to the body side, negative lens component L1g of both the concave configuration, and negative lens component L1h of the meniscus configuration where the convex was turned to the body side.
[0036] Moreover, the 2nd lens group G2 Sequentially from the aperture-diaphragm AS side, negative lens component L2a of both the concave configuration, Positive lens component L2b of both the convex configuration where the convex strong against an image side was turned, and negative lens component L2c of both the concave configuration, Positive lens component L2e of both the convex configuration which turned th convex strong against the positive lens component L2d and aperture-diaphragm AS side of both the convex

configuration where the convex strong against an image side was turned, Positive lens component L2f of both the convex configuration where the same convex strong against the aperture-diaphragm AS side was turned, Positive lens component L2g of both the convex configuration where the same convex strong against the aperture-diaphragm AS side was turned, Positive lens component L2i of both the convex configuration which turned the convex strong against the negative lens component L2h and aperture-diaphragm AS side of both th concave configuration where the concave surface strong against an image side was turned, It consists of negative lens component L2j of a meniscus configuration which turned the convex to the aperture-diaphragm AS side, positive lens component L2k of a meniscus configuration which turned the convex to the aperture-diaphragm AS side, and positive lens component L2l. of the meniscus configuration where the convex was similarly turned to the aperture-diaphragm AS side.

[0037] The value of the item of this example hangs up over following Table 3. In this example, it is 1/4 time (contraction) the scale factor of the whole system of this like the 1st example of the above, and the numerical aperture NA by the side of Wafer W is 0.6, and the working distance by the side of Wafer W is 15.0mm. And for the cata-dioptric system of this example, the image quantity from the optical axis Ax on Wafer W has the exposure field of the shape of a 30mmx6mm slit in the range to 15.3mm like the 1st example of the above. Moreover, the beam splitter BS in this example is a 170mmx170mmx190mm rectangular parallelepiped configuration.

[0038] Moreover, in Table 3, the sequence of going to the 2nd page equivalent to the Wth page of the wafer as the image surface from the 1st page equivalent to the pattern formation side of the reticle R as a body side shows the radius of curvature r, Spacing d, and the ** material of each side. All over Table 3, between Reticle and the concave mirror M, the sign of the radius of curvature r of each field makes forward the case where a convex is turned at Reticle R side, and makes forward the case where a convex is turned at a beam splitter BS side, between the beam splitter BS and Wafer W. Moreover, the sign of Spacing d is just taken by other optica paths for negative according to the optical path which reaches the directional change side of a beam splitter BS from a concave mirror M. And it is CaF2 as ** material. Fluorite and SiO2 Quartz glass is expressed, respectively. Here, the refractive index in the criteria-for-use-of-food-additives wavelength (wavelength of Ar laser: lambda= 193.4nm) of quartz glass and fluorite is as follows. Quartz glass: 1.56019 fluorite : 1.50138

[0039]

[Table 3] [The 3rd example]

d0 = 96.384 r d ** material 1 1566. 352 33.601 SiO2 2 - 258.445 42.686 3 - 303.358 35.000 CaF2 4 254.513 39.688 5 408.129 35.000 SiO2 6 - 292.562 0.500 7 238.980 28.106 SiO2 8 177.718 35.520 9 236.585 35.000 SiO2 10 258.786 35.249 11 -1574.830 35.000SiO2 12 - 195.650 0.50013 -220.42925.000CaF2 14228.713 7.071 15 380.419 35.000 SiO2 16 274.848 10.84717 0.000 170.000 SiO2 Beam splitter BS 18 0.00010.000 19 644.053 -10.000 The lieberkuhn M20 0.000-85.000 SiO2 21 0.000 85.000 SiO2 Directional change side 22 0.000 10.000 23 0.00016.475 Aperture-diaphragm AS24 -240.493 27.541 SiO2 25 609.289 0.500 26 648.361 39.879 CaF2 27-161.540 0.500 28 - 161.204 15.000SiO2 29 432.174 2.340 30 513.767 39.791 CaF2 31 - 245.896 0.500 32 397.672 35.000 CaF2 33 -1373.400 0.500 34 350.822 28.205 CaF2 35 -1504.430 0.500 36 152.096 44.808 CaF2 37 -3015.120 0.546 38 -3831.930 15.302 SiO2 39 292.927 0.657 40 122.58834.934CaF 411224.997 0.539 42 1218. 161 15.188 SiO2 43 74.562 8.605 44 108.074 35.000 SiO2 45 377.013 1.406 46 259.877 35.000 SiO2 47 767.722 15.000 The value corresponding to conditions in the 3rd example is shown below.

(1) 1/betaM =-0.116(2) L1 /-- f -- two -- = -- 2.053 -- (-- three --) -- beta -- two -- /-- beta -- = - 0.18 -- (-- four) -- D -- one -- /-- fM -- = -- 0.40 -- (-- five --) -- D -- two - NA/f -- two -- = -- 1.37 -- (-- six --) -- (-- phi -- B -- one -- /-- two - four -- dW - NA --) -- /(f2 and 2) -- = -- 3.07 -- drawing 7 -- the transverse aberration Fig. of th 3rd example -- being shown -- . Here, it is drawing 7 (a). It is a transverse aberration Fig. in one hundred percent-(15.3mm of image quantities) of image quantities, and is drawing 7 (b). It is a transverse aberration Fi in 50 percent (7.65mm of image quantities) of image quantities, and is drawing 7 (c). It is a transverse aberration Fig. in 0 percent (on an optical axis: 0.0mm of image quantities) of image quantities. In addition, in each transverse aberration Fig., a continuous line expresses the aberration curve in criteria wavelength (lambda = 193.4nm), and an aberration curve [in / in a dotted line / lambda= 193.5 nm wavelength], an aberration cur [in / in an alternate long and short dash line / the wavelength of lambda= 193.45nm], an aberration curve [in in a broken line / lambda= 193.35nm], and a two-dot chain line express the aberration curve in lambda= 193.:

nm wavelength, respectively. Each transverse aberration Fig. shown in drawing 7 shows that the cata-dioptric system by this example has the image formation engine performance of NA=0.6 which the chromatic-aberratic amendment by 193.4nm**0.1nm is especially made by amending aberration good in spite of having attained b numerical aperture very much, and was excellent.

[0040] In addition, as for the directional change side of a beam splitter BS, in each above-mentioned example, is desirable that it is the polarization separation side which consists for example, of dielectric multilayers. At this time, lambda/4 plate is formed on the field which counters the concave mirror M of a beam splitter BS. Moreover, when aberration occurs in the above-mentioned dielectric multilayers, it is the 1st lens group G1 of beam splitter BS. The field which counters, the field which counters a concave mirror M side, and the 2nd lens group G2 It is desirable to prepare the thin film which negates the aberration of the fields which counter generated in dielectric multilayers on the whole surface at least. What is necessary is just to use the thing of a configuration of that thickness differs from a refractive index partially, for example as such a thin film.

[0041] moreover, each above-mentioned example -- setting -- the 1st lens group G1 from -- the flux of light which faces to a concave mirror M -- the directional change side of a beam splitter BS -- penetrating -- and a concave mirror M to the 2nd lens group G2 Although the going flux of light is the configuration reflected in respect of directional change of a beam splitter BS the 1st lens group G1 from -- the flux of light is reflected in respect of directional change of a beam splitter BS, and it leads to a concave mirror M, and the directional change side of a beam splitter BS is penetrated for the flux of light from a concave mirror M -- making -- the 2nd lens group G2 Also as a configuration to draw, it is equivalent on an optical design.

[0042]

[Effect of the Invention] As above, according to this invention, a big numerical aperture can be attained, and sufficient image side working distance can be secured to an image side, the miniaturization of a beam splitter can be attained further, and resolving of a quarter micron unit can be attained.

[Translation done.]

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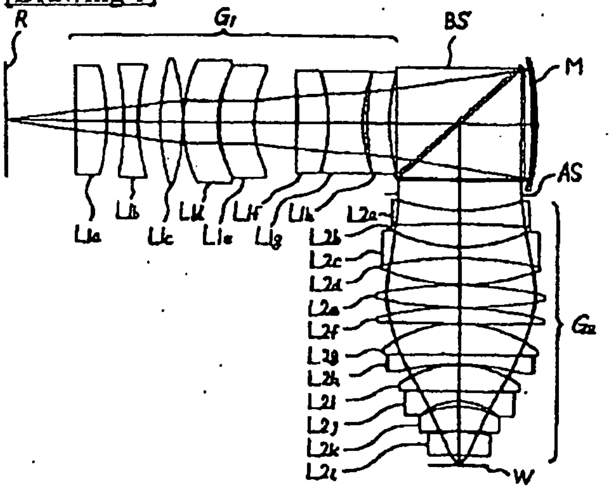
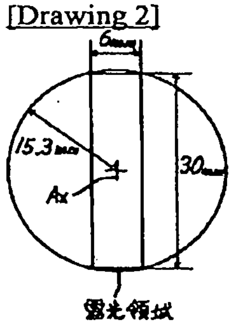
1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DRAWINGS

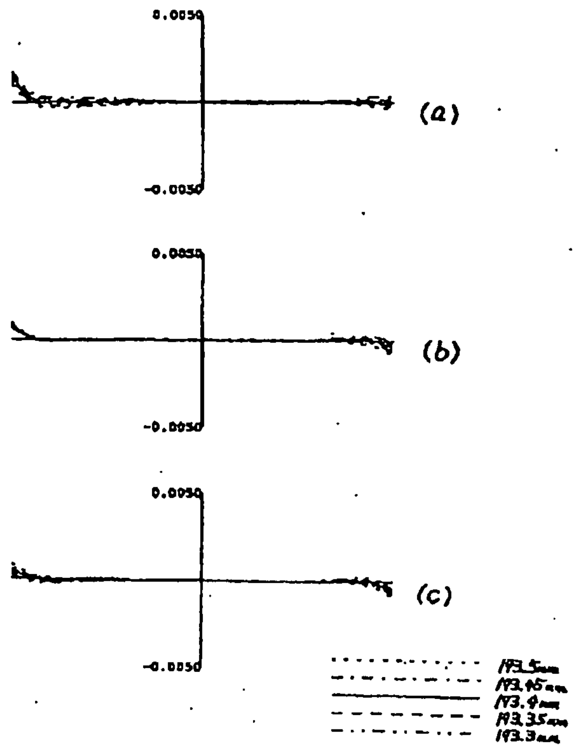
[Drawing 1]



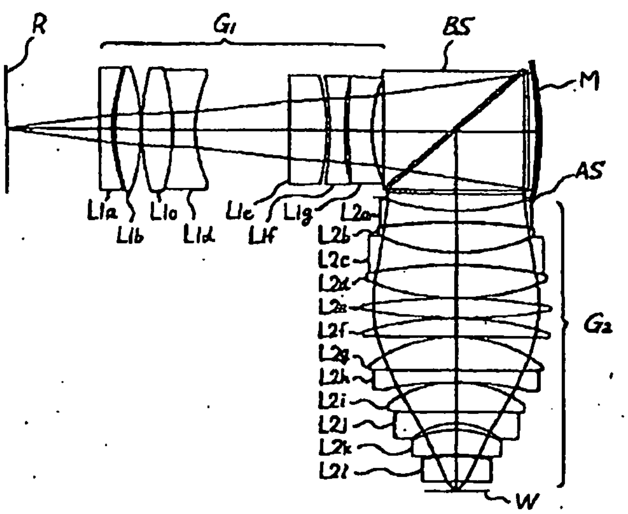
[Drawing 2]



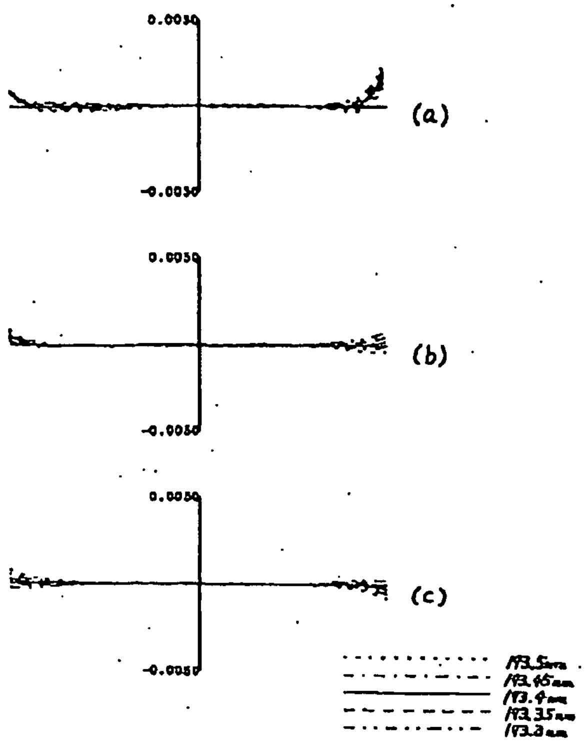
[Drawing 3]



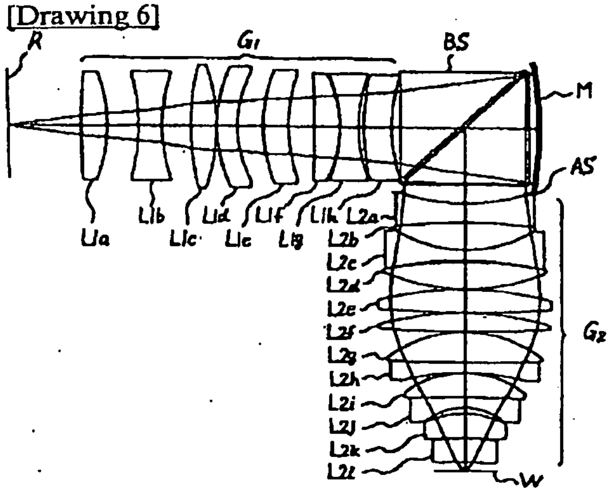
[Drawing 4]



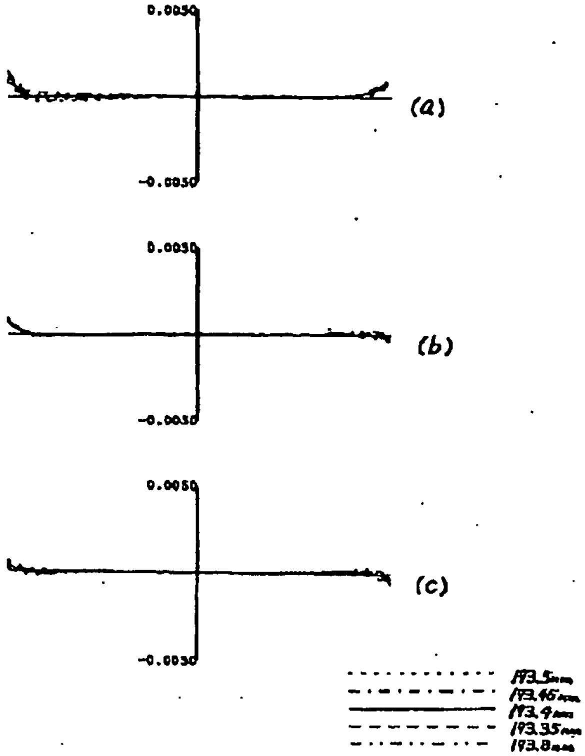
[Drawing 5]



[Drawing 6]



[Drawing 7]



[Translation done.]